craig richardson

a new hurricane protection plan for north carolina's barrier islands

Scenario

Scene: Palm Isle Beach, North Carolina
Date: August 15, 1976
Time: 6:00 a.m.

Only 8 hours earlier, the numerous vacationers visiting Palm Isle Beach had breathed a casual sigh of relief. The hurricane advancing up the eastern seaboard had seemed to be sliding out to sea toward the northeast. The hurricane warning which had been in effect earlier in the day was lifted. The visitors settled down for a peaceful night of rest.

The weekend had proven bad enough for the crowd of vacationers enjoying their last opportunity of the year to bask in the Carolina ocean sun. Rains and high seas had begun Thursday night with the threat of a hurricane and continued through Saturday. But with the storm's movement out to sea, the possibilities for a subsequent week of sun, fishing, and surf seemed good.

But events changed dramatically. About 11:30 p.m., August 14, the storm took an abrupt move westward, heading for the southeastern North Carolina coast. Within the hour, weather service offices at Wilmington and Cape Hatteras re-issued a hurricane warning for Myrtle Beach north to Cape Hatteras, stating there was a high probability the hurricane would not move as far to the northeast as predicted, and coastal residents should be prepared to experience hurricane conditions within 9 to 10 hours.

The Office of Civil Preparedness went into action, warning beach residents and vacationers. The hurricane bulletin issued at 3:30 a.m. forecast a storm-surge of 5-7 feet from the North Carolina line north to the Cape Fear River. It recommended that all persons located on the barrier islands be evacuated since the entire area was to be subject to flooding and storm surge. By 5:30 a.m., only one-quarter of the people had been evacuated over the island's single bridge. Heavy winds and rain cut traffic to a crawl. Automobiles began to bottleneck and back onto the island. Several small accidents along the highway accentuated the problem and added to the confusion.

Winds picked up to a steady 40 miles per hour with gusts as high as 60 m.p.h. The Weather Bureau reported wind speeds near the eye of the hurricane to be 110 m.p.h. By 7:30 a.m. the line of cars backed behind the bridge convinced many to try and "wait it out" on the island — and by 8:00 a.m. the emergency patrol was turning people away from the evacuation route as the flood waters began lapping at the bridge's sides. At 8:30 a.m., flood waters reached the top of the bridge and were likewise lashing the shores. At 9:30 a.m., with only half of the population evacuated, the remaining Palm Isle community braced themselves for the brunt of the storm's attack.

introduction

The scenario just outlined is ficticious - in fact no storm of hurricane intensity has affected the North Carolina coast since 1971. But the potential of a similar event occurring at any of the beach communities on North Carolina's barrier islands, and the possibility of such an event inflicting unnecessary loss of life and property damages to beach residents, tourists, and the coastal environment itself, is probable as long as existing hurricane protection measures are continued. What are the chances coastal North Carolina will suffer a hurricane attack? What damages occur when this most dreaded of natural storms strikes? What existing actions are being used to address the hurricane problem? Is the program adequate? If not, what actions need to be included to insure protection of life, property, and the amenities so unique to the coastal environment?

This study attempts to answer these questions for the beach communities located on the string of barrier islands stretching the distance of the North Carolina coast. First, an examination of hurricane occurrences is made to determine the probability of

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hurricane landfall; that analysis is followed by an assessment of damages to life and property by such events. Next, attention is focused on actions used to protect the barrier islands from hurricane attack. The report concludes with an analysis of the existing program and sets forth recommendations for a new hurricane policy and action plan for the local barrier island communities.

is the threat real?

Records of hurricanes along the North Carolina coast prior to establishment of the Weather Bureau in 1879 have proven, at best, sketchy, making classification of these early storms from historical sources a matter of conjecture. For this reason, a record of major North Carolina hurricanes was tabulated since 1896 (see Table 1).

Before proceeding with the analysis, however, it should be recognized that although the assignment of probabilities to hurricane attacks based on historical records is plausible, the prediction of future storms, even in a probabilistic sense, is uncertain. Furthermore, average hurricane return intervals are just that, average return intervals. A recurrence interval of 20 years implies a storm of specified intensity will attack on the average of once in 20 years. The probability of similar storms striking in successive years may be small, but it is not impossible. Frequency of hurricane attack can be misleading to the degree that low percentages underplay the vulnerability of an area to hurricane attack. For instance, a beach community may not have been affected by a major storm in 20 years. However, the community could still be subjected to severe hurricane attack for four or five consecutive years.

"Historical records indicate 33 major hurricanes have affected the North Carolina coast since 1933."

In his *Assessment of Research in Natural Hazards*, Gilbert White indicates the probability of a tropical storm of hurricane proportions hitting the North Carolina coast to be from 5-11 percent in a given year, depending on the location.[1] Historical records indicate 33 major hurricanes have affected the North Carolina coast since 1896.

Table 1**

Major North Carolina Hurricanes (1896-1976)

(1) August 17, 1899
(2) October 30, 1899
(3) July 11, 1901*
(4) September 15, 1903
(5) September 14, 1904
(6) November 13, 1904
(7) September 17, 1906*
(8) July 30, 1908*
(9) August 31-September 1, 1908
(10) September 2, 1913*
(11) July 19, 1916
(12) August 24, 1918
(13) September 22, 1920*
(14) August 25, 1924
(15) December 2, 1925
(16) September 12, 1930
(17) August 22-23, 1933*
(18) September 16, 1933*
(19) July 21-25, 1934*
(20) September 18, 1936
(21) September 21, 1938
(22) August 1, 1944*
(23) September 14, 1944*
(24) August 24, 1949*
(25) August 13, 1953*
(26) August 30, 1954*
(27) October 15, 1954*
(28) August 12, 1955*
(29) August 17, 1955*
(30) September 19, 1955
(31) September 27, 1958
(32) September 11, 1960*
(33) September, 1971*

**Those storms recorded by Paul J. Herbert and Glenn Taylor, "Hurricane Experience Levels of Coastal Populations - Maine to Texas" as affecting the North Carolina coast.*

***It must be noted that in examining the literature of past hurricane occurrences, some degree of incongruity was discovered. Taylor and Herbert in "Hurricane Experience Levels of Coastal Populations - Maine to Texas," sited 19 North Carolina hurricanes since 1900. Carney and Hardy in "North Carolina Hurricanes: A Listing and Description of Tropical Hurricanes Which have Affected the State," list 57 tropical storms in the twentieth century (including the 2 major hurricanes of the 1970's not listed in their 1967 publication). The discrepancy can be explained as a matter of definition. The Herbert-Taylor report used the Saffir/Sim Hurricane Disaster Potential Scale which considers direction, wind speed, cential pressure and other variables affecting the intensity and destructive capacity of the storm. The Carney-Hardy study listed "all tropical storms (on which any record could be found by the authors) which have struck North Carolina, had any appreciable effect on the state, or passed close enough offshore to have been a serious threat to the coastal area."[2] For the purposes of this study, a record of hurricane occurrences since 1896 has been compiled using these two sources, while trying to disclude those storms where little damage was recorded. A hurricane was defined as a storm in which maximum velocity (average wind speed over a 5 minute interval) wind speeds exceeded 50 miles per hour.*

Further analysis of the data (Table 2), through tabulation of hurricane incidents over a ten year period, reveals a relatively stable level of hurricane occurrence over the 8 time periods (between 2-7 occurrences per decade) — indicating that the potential for hurricane attack on the North Carolina coast is relatively consistent.

"A closer analysis reveals the same amount (of hurricanes), 73 percent, have occurred between July 19 - September 19, the last two months of the beach season, when population on the barrier islands is at its highest levels"

time of hurricane occurrence

Another variable meriting consideration in an analysis of hurricane impact is the time of year hurricanes are most likely to occur. In charting the 33 storms affecting the North Carolina coast by month of occurrence (see Table 3), the statistics show approximately 73 percent of past hurricanes struck in August and September (24 of the 33). A closer analysis reveals the same amount, 73 percent, has occurred between July 19-September 19, the last two months of the beach season, when population on the barrier islands is at its highest levels.

damages

Destruction and damage to the North Carolina coast from hurricanes has been great and is increasing. As the records indicate, however, statistics concerning hurricane damages have been lax, at best. Furthermore, even if substantial information on property damages and other losses was available, it would still remain difficult to assess phenomena such as psychological injury, long term losses to the resort economy, the effects of freshwater floods and shifting sands on oyster beds, weakened utility systems, and lost income due to temporary unemployment.[3]

Information on the losses suffered in North Carolina since 1896 from major hurricanes has been compiled (see Table 4). But much of the early information gathered comes from newspaper accounts (sometimes of single incidents) and Weather Bureau reports. Some of the information gives dollar damage amounts for a specific area. Other accounts reveal figures for the entire state. The only detailed account collected was that used in a report on the four hurricanes of 1954-1955.[4]

Table 2

Major Hurricane Occurrences per Decade in North Carolina (1896-1976)

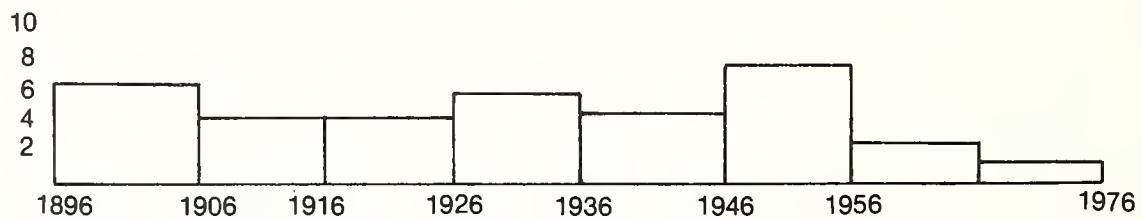

Table 3

Major Hurricane Occurrences by Month in North Carolina (1900-1976)

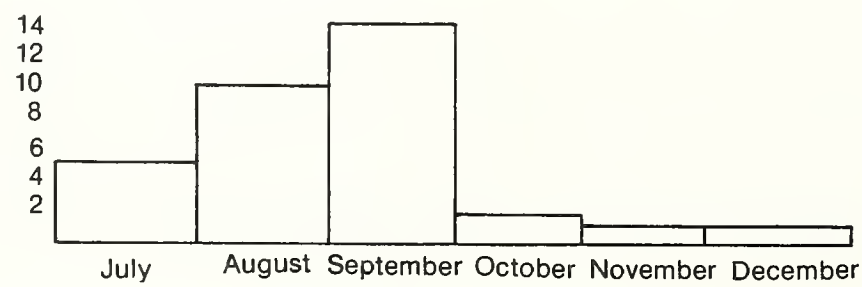

Table 4*

Hurricane	Damages
(1) August 17, 1899	Hatteras Island 4-10 feet under water-all piers and bridges destroyed.
(2) October 30, 1899	Damages around the Wilmington area assessed at $200,000
(3) July 11, 1901	No record of damages
(4) September 15, 1903	No record of damages
(5) September 14, 1904	No record of damages
(6) November 13, 1904	No record of damages
(7) September 17, 1906	Considerable damage to property and shipping
(8) July 30, 1908	Damage recorded as "immense."
(9) August 31-September 1, 1908	Heavy flooding
(10) September 2, 1913	Property damage in North Carolina assessed at $4,000,000-$5,000,000
(11) July 19, 1916	Light damage
(12) August 24, 1918	Light damage
(13) September 22, 1920	Little record of damages
(14) August 25, 1924	Light damage
(15) December 2, 1925	Little record of damages
(16) September 12, 1930	Little record of damages
(17) August 22-23, 1933	Storm damage estimated at $250,000
(18) September 16, 1933	Damage in North Carolina assessed at $3,000,000
(19) July 21-25, 1934	Little record of damages
(20) September 18, 1936	Damage estimated at $55,000 in Hatteras area
(21) September 21, 1938	Light damage
(22) August 1, 1944	Damages in southeast North Carolina estimated at $2,000,000
(23) September 14, 1944	Damage to buildings and crops estimated at $1,450,-000
(24) August 24, 1949	Damages estimated at $50,000
(25) August 13, 1953	Damages to buildings and crops assessed at $1,-000,000.
(26) August 30, 1954	Considerable erosion. Damage to piers, roofs, television antennas estimated at $225,000
(27) October 15, 1954	19 deaths
	Losses to farm buildings 50,500,000
	Minor damage to dwelling units 59,000,000
	Churches and public schools 1,000,000
	Public Utilities 1,800,000
	Municipal and County facilities 8,000,000
	Highways 500,000
	Fishing Industry 1,500,000
	Forests 3,000,000
	Total property damage 125,300,000
(28) August 12, 1955	Agriculture 131,000,000
(29) August 17, 1955	Private Property 49,570,000
(30) September 19, 1955	Public properties and utilities 7,202,000
	Public highways 1,870,000
	Total Property damage 189,642,000
(31) September 27, 1958	Damage at Wrightsville Beach assessed at $221,800
(32) September 12, 1960	Estimates well in the millions of dollars
(33) September, 1971	Light damage

**Damage estimates from the North Carolina hurricanes (1896-1976) were drawn from the North Carolina Council of Civil Defense's* North Carolina Hurricane Project, *and Charles B. Carney and Albert V. Hardy's "North Carolina Hurricanes: A Listing and Description of Tropical Cyclones Which Have Affected the State."*

Courtesy of Department of Natural and Economic Resources

Damage from hurricane storm surge is a threat to the entire North Carolina coast

Even though this information is given on a statewide basis, the majority of damages occurred on the barrier island communities and adjoining farmlands of eastern North Carolina. During these four storms, all the barrier islands were ravaged by storm surge and flooded to varying degrees.[5] Homes were destroyed, businesses flooded, roads ruined, and the area economy overturned for weeks, leaving little doubt about the catastrophic nature of hurricanes. Recognizing the imminent dangers of hurricanes, let us now examine the existing state of the art for hurricane protection along the North Carolina coast.

existing actions

Existing actions used to protect property and life from hurricane attack can be separated into four categories: (1) warning, evacuation, relief, and rehabilitation in the Office of Civil Preparedness, (2) protection through dune stabilization, (3) protection through wind and wave-resistent building design criteria as adopted in the North Carolina State Building Code, and (4) relief and protection through the National Flood Insurance Program.

Until recently, the brunt of this hurricane protection-relief activity has focused upon the first two strategies: the "clear and present danger" measures offered through the Office of Civil Preparedness when hurricane attack is imminent, and the protective dune stabilization program proposed by the Corps of Engineers. The other alternatives, building design criteria and land use controls, have been either neglected (in the case of the North Carolina State Building Code) or just recently implemented (National Flood Insurance Program), and have thus been of little consequence in hurricane protection policies or plans.

warning, evacuation, relief, and rehabilitation

Direct responsibilities for coordination of warning activities, evacuation, relief and rehabilitation during time of hurricane siege rest in the hands of the local Office of Civil Preparedness in each coastal county. These local offices are aided in their planning and preparation by the State Office of Civil Preparedness in Raleigh. The North Carolina program is divided into six geographical regions, each possessing an office coordinator who acts as liaison between the state office and localities. These regional offices advise the local Civil Preparedness Officer, who in turn is responsible for setting up warning systems, evacuation routes, and relief centers for the local areas. The regional offices disseminate materials and information to the county directors with ideas on how to structure a Natural Disaster Preparedness Committee, types of officials to include (i.e., the mayor, the Red Cross, the Police Department, City Engineers, Newspaper Officials, and Television Officials), information on methods for educating the community, aids in planning locations for emergency operating centers, the supplies and other types of equipment needed for the center, and strategy for coordination of community emergency activities with the U.S. Weather Bureau, the North Carolina National Guard, and the State Office of Civil Preparedness.

Presently, all 17 of the coastal counties have a local Civil Preparedness Officer. But, in many cases, the local official is plagued by low public awareness of potential hurricane attack (especially since a

direct hurricane landfall has not occurred since September 12, 1960). Typically, no community action is taken to insure bridge capacities are adequate, and public participation and consciousness of the necessary emergency actions is low. The local Civil Preparedness Officer is forced into a low-key role by the community until a crisis occurs — and then is expected to smoothly direct community-wide evacuation and relief procedures amongst a citizenry unfamiliar with the proper emergency actions.

"... this protection measure (dune stabilization) has proven costly and, in some ways, counter productive as a hurricane policy."

dune stabilization

Dune stabilization, another form of protection, has taken place at various intervals along the state's barrier islands. In its natural condition, the seaward boundary of a barrier island is characterized by a line of shifting sand dunes breached by intermittent overwash fans which provide a natural outlet for exceptionally heavy seas. Dune stabilization involves the strengthening and fortification of sand dunes and the closing of overwash fans, theoretically to prevent a storm surge from flooding the island. However, this protection measure has proven costly and, in some ways, counterproductive as a hurricane protection policy.

The experience at the Cape Hatteras National Seashore and Recreational Area (CHNSRA) dramatically outlines the problems accompanying dune stabilization activities. Shortly after organization of CHNSRA, the National Park Service, in conjunction with the Corps of Engineers, initiated a long-range plan to alleviate the erosion problems generated by the natural processes on the barrier islands. In order to stablize inlets, widen the beaches, ameliorate drainage problems and protect the inhabitants from severe storms, a dune stabilization program was launched.

By the late 1960's the fruits of their labor began to emerge. The steepening of the frontal dunes along the shoreline (the primary form of protection) stepped up the erosion process. The effect of this acceleration can be seen along the Cape Hatteras National Seashore and Recreation Area where the beach berm has been shortened over the past 25 years to 90-150 feet in width (a natural barrier island berm is 400-500 feet).[6] Secondly, with the filling and stabilization of the frontal dune, flood hazard from the sound side has actually increased. On a natural barrier island, a severe flood coming from the sound pushes over the island and is able to dissipate on the ocean side through the overwash fans. However, along CHNSRA where the frontal dunes have been stabilized, the saline water is blocked by the unbroken line of dunes and is forced to remain on the island for days, destroying the vegetation.[7]

In addition to the natural problems created by dune stabilization, there exists a socio-psychological problem which could exacerbate the disruptive character of this kind of hurricane protection strategy in a more developed area. It emerges in the form of a false sense of security which protective dunes encourage. Its shape burgeons with such activities as increased residential and commercial speculation by the developer, second home investment by the homeowner, and the neglect of the other types of protective measures (building design, evacation plans etc.) by the public official — until the record storm occurs, destroying the "stabilized dunes" and all the new development investments behind them.

north carolina state building code

Although neglected by most of the coastal counties and their municipalities, another preventative action designed to protect people and property from hurricanes in coastal North Carolina is embodied in the model North Carolina State Building Code. Due in part to the tremendous damages suffered by the 1954-1955 hurricanes, the General Assembly in 1958 included amendments to the codes for hurricane prone counties to aid in the prevention of building damage from hurricane floods and winds. The requirements are twofold: (1) design, and (2) anchorage requirements to protect buildings from wind and wave action.[8] Requirements for wood and frame buildings included anchorage at roof-to-

Development insensitive to the natural island processes generates unnecessary damages from hurricanes

Courtesy of Department of Natural and Economic Resources

walls, walls-to-floor, floor-to-foundation, and foundation-to-footing joints. Requirements for masonry or brick homes also include that the roof be anchored to the foundation with steel rods.[9]

national flood insurance program

Another program which could prove fruitful in protecting life and property from hurricane attack is the National Flood Insurance Program (NFIP), an effort by the federal government to provide flood insurance to homes and businesses, while discouraging the use of flood prone areas through building and land use restrictions. The program is administered at the federal level through the Department of Housing and Urban Development and in North Carolina through the Department of Natural and Economic Resources, Division of Community Assistance. NFIP is operated as a two phase effort. Phase I, (the emergency phase) is designed to familiarize the counties and municipalities with the program and allow them time to make studies of the flood-prone areas. It requires building permits to be issued for all structures built in the designated flood-prone areas and minimal design considerations be followed when allowing development in flood hazard areas.

Phase II (the regular phase) requirements are more demanding. These include detailed studies of flooding to ascertain specific flood levels, followed by elementary land use controls and building design criteria in the form of flood plain ordinances.

Along the coast, design criteria follow the logic used in riverine systems with the exception of the use of "high velocity" and "non-high velocity" zones. The high velocity zone is that area designated as vulnerable to flooding and wave action during the storm. The non-high velocity zone is the area not plagued by wave action, but still flooded during the storm.

For purposes of flood plain ordinance requirements, the 100-year flood* is used. No discernable difference in terms of design regulations exists between requirements for the "high velocity" and "non-high velocity" zones. Both area ordinances require that the first floor of structures be built at or above the 100-year flood level (in the "high velocity" zone, the building must be above flood waters and wave action) and, constructed on pilings of a break-away nature to allow flood water easy access under the floor.

The effect the NFIP will have in ameliorating hurricane protection, however, is still nebulous. The status of the program along the North Carolina coast varies. Most all communities have entered Phase I (the emergency phase) of the program. But few have been able to complete the studies required to enter Phase II, where some form of land use control and building design criteria are required in the flood hazard areas. Before these more specific requirements have been implemented by the barrier island communities, the efficacy of NFIP in relieving and protecting coastal residents from flood phenomena will remain uncertain.

analysis of existing actions: considering the natural processes

After examining the alternative protective actions against hurricane attack, it becomes evident that one issue vital to a sound hurricane policy is consistently skirted: the effects which human actions (such as building and dune stabilization) have

*The 100-year flood is defined as that flood which has a one percent chance of occurring in any given year.

Roads constructed too near the shoreline tend to disrupt natural barrier island processes

Courtesy of Department of Natural and Economic Resources

on the barrier island's naturally resilient capacities in the face of hurricane siege - and the actions necessary to maintain the natural island equilibrium in order to protect, enhance, and maintain the unique values of the coastal environment. Actually, there would be no natural problems if man did not occupy the barrier islands. By its nature, the barrier island provides a dynamic environment which at first glance appears as nothing more than shifting sands, but actually supports a highly stablized ecosystem.

Tampering with such a sensitive process (many times done when man inhabits the barrier island) creates severe problems. Dune stabilization, plugging the overwash fans, extensive construction in sensitive shoreline areas, or allowing rampant destruction of the maritime forests could throw the island's ecological equilibrium off balance. Proper building design criteria and set-back lines, do not in themselves constitute a comprehensive hurricane policy. Elevated residences could be constructed in overwash fans and be properly set back from the ocean. But obstruction to the island's resilient processes during time of hurricane siege might still occur if homes block the passage of storm surge from the shoreline or floodwaters from the sound side of the island. Only when building design criteria and set-back lines are integrated with sound land use controls will the viability of these resilient processes be maintained.

"Design criteria for buildings should be adopted in the form of (1) standards required by the National Flood Insurance Program (pilings and elevation requirements) and (2) the standards from the North Carolina State Building Code."

A hurricane policy, then, must strike a sensitive balance between protecting property and life and the natural processes which make the coastal environment unique. The one-dimensional emphasis on the tasks of the Office of Civil Preparedness and the detrimental and costly dune stabilization activities must shift to a more comprehensive strategy which places heavier emphasis on land use controls and building design criteria. Instead of ignoring the intensity, location, and quality of development on the barrier islands and concentrating on immediate emergencies when they arise, the new hurricane policy and action plan should address these land-use and design issues in order to prevent severe evacuation problems and damages, and protect the barrier island environment.

The dune stabilization program must end. Overwash fans and the dune system should be protected to insure the viability of the natural processes so important to the island's resiliency during hurricane attack. Building elevations and flood-proofing should be required to protect properties from damages and aid in preservation of the natural island environment. Innovative subdivision regulations should be encouraged which sensibly address the natural problems of the island environment. Evacuation capacities should be considered when compiling holding capacity levels. Finally, the warning, evacuation, relief and rehabilitation efforts of the local Office of Civil Preparedness should be given more recognition in the community as it attempts to work in conjunction with these other efforts. More specific tools for action are outlined below.

the action plan

Warning, evacuation, relief, and rehabilitation during time of hurricane attack should continue to be directed by the local Office of Civil Preparedness. Evacuation plans should be drawn for each jurisdiction. A holding capacity should be calculated from these Civil Preparedness reports by each community, and land use controls implemented which assure that all people on the islands can be safely evacuated in the event of hurricane attack. A stronger effort should be made to heighten public awareness of the Office of Civil Preparedness in the coastal communities. Public participation in preparing for evacuation and other emergency procedures should be encouraged.

Another form of rehabilitation is available from the National Flood Insurance Program.* All municipalities and counties should be encouraged to enroll in Phase II of the program as soon as possible. Such actions will make flood insurance available to all homeowners.

Design criteria for buildings should be adopted in the form of (1) standards required by the National Flood Insurance Program (pilings and elevation requirements) and (2) the standards from the North Carolina State Building Code. These should be synthesized into a simplified county-municipal code in which all requirements (elevation above flooded areas with break-away pilings, anchorage, and tie-down requirements for roofs, walls, etc.) are considered. Specific ordinances for mobile home and buildings should include:**

*Even though the National Flood Insurance Program is included in the hurricane strategy, there exists some doubt as to whether it encourages building in fragile areas by subsidizing (through insurance) the participants. Apparently, a compromise has been struck between the "purists" desire to prohibit any kind of development in these areas and the "developers" who argue against any form of control.

**These ordinances have been modeled after those used in the *Comprehensive Land Use Plan, City of Sanibel, Florida*, by Wallace, McHarg, Roberts and Todd.

For Mobile Homes:

(1) Assurance that all structural components (wall, frame, windows, tie downs, etc) can withstand the impact of a 100-year storm.
(2) Assurance that the electrical and sanitary components installed are fitted so as not to be source of untreated effluent or other damages during the 100-year storm.

For Buildings:

(1) Provisions for elevation of the lowest floor of all new construction or any substantial improvements to existing units be *X* feet above mean sea level (*X* feet in high velocity zones being the level at which the structure would not be effected by wave or wind action from the 100-year storm and, in the non-high velocity zones, where the structure would not be affected by flood waters from the 100-year storm. These levels will depend on a number of variables and should be obtained from the Flood Plain studies by the Corps of Engineers).
(2) Provisions that portions of new construction or any substantially improved building which is below required elevation levels be used only for parking, storage, utility rooms, workshops and other uses normally associated with accessory buildings and be constructed of breakaway materials in order to allow storm driven wind and water to pass through the lower portions of the buildings without threatening the integrity of elevated sections of the building.
(3) Provisions that any sewer, water, electrical or other utility service system installed be flood-proofed to at least *X* feet above mean sea level (X feet being the same height as the lowest floor). The applicant must include certification by a registered professional engineer or architect that flood-proofing methods are adequate to withstand pressures from the 100 year storm.[10]

Subdivision Regulations should be adopted which require consideration of the effects man-made design has on the natural barrier island processes during times of hurricane siege. A Planned Unit Development process, espousing flexible means of achieving harmonic design with the natural island elements and containing specific requirements concerning dune setbacks and building elevation levels (as expressed above), would seem most ideal. Such a process should require a road design eliminating the open channel effect produced by constructing roadways perpendicular to the ocean. Likewise, such a process should encourage innovations such as the staggered lot concept and other new designs which push beach development in more environmentally sensible directions.

Zoning Regulations should be drawn by the county and municipalities in conjunction with Areas of Environmental Concern (AEC) categories of the Coastal Area Management Act (CAMA). Such a measure should allow for preservation of those natural areas on the barrier islands critical to the maintenance of the island's resiliency during time of hurricane siege. It should include protection of the dune system (more than the primary dune) and the overwash fans.

This could be done by the insertion of a conservation zone in the local zoning ordinance which follows the same boundaries as the AEC category (see Figure 1). This general conservation zone should have various subcategories, for example, a Conservation-Residential zone, a Conservation-Commercial zone, etc, to accommodate situations where the AEC (and conservation zone) crosses several different local zones. If the standard zoning process is implemented, the allowable uses for each sub-category (Conservation-Commercial, Conservation-Residential) can be defined in conjunction with the AEC guidelines. If some type of evaluation system with a site-plan approval process is used, specific criteria for development in these areas should be defined. As such, this procedure would establish guidelines for the minor development permit process under CAMA, simplify the state-local problems involved with managing areas of environmental concern, organize the AEC concept at the local level, and provide the Coastal Resources Commission specific information which would aid in their review of major developments in the local AEC category.

"(Zoning regulations) should allow for preservation of those natural areas on the barrier islands critical to the maintenance of the island's resiliency during time of hurricane siege."

Alteration of Areas of Environmental Concern in Coastal Area Management Act is needed. As mentioned above, the local zoning regulations for hurricane protection should be implemented in conjunction with the AEC designations of the Coastal Resources Commission. As such, an extension of the Dunelands (Other Dunes) category (6.1.2) under the Natural Hazards section would need to be made. The description should read:

> Ridges or mounds of loose wind-blown material, usually sand which begins on the landward margin of the frontal dune as a series of sand mounds and trough areas that act in conjunction with the frontal dune to aid in protection and absorption of wave and wind energy. They may be barren, partially or completely vegetated with grasses or woody vegetation.

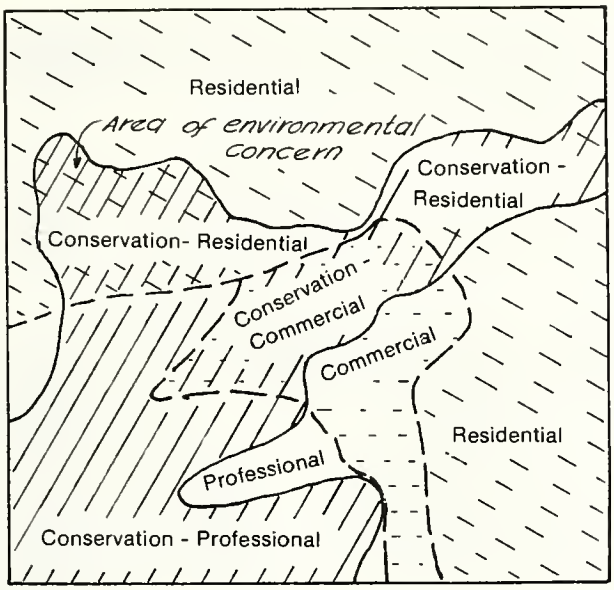

Figure 1

Such a definition allows for consideration of the dune system as a protective barrier against hurricane attack with full knowledge that one day the frontal dune may no longer exist — as a secondary dune takes its place.

Also, an addition to Section 6, Natural Hazard Areas, should be made in the form of a category for Overwash Fans. It should be described as:

> Those tongue-shaped terraces of fans, built by the sand carried from storm overwash. They are found between breaches in the frontal dunes stretching landward. The type and intensity of vegetation depends on the frequency and strength of storm waters which inundate the area.

The overwash fan, along with the dune system, aids in the resiliency and stability of the shoreline during hurricane attack — and by its own composition allows extension of the island's backside, which aids in the maintainance of an ecological equilibrium within the island system.

conclusion

Examination of historical records on hurricane occurrences along North Carolina's string of barrier islands shows the real potential of hurricane attack in this coastal area - an incident which, in all likelihood, would create severe storm surge and untold damages from hurricane flood waters, wave action, and winds. Analysis of alternative action plans for hurricane protection reveals the focus on past programs has fallen short of a truly comprehensive hurricane protection policy on several accounts. First, the focus on past programs has rested solely on the activities of the Office of Civil Preparedness and the impractical protective measures of dune stabilization, while neglecting more preventative actions such as the implementation of building design criteria and land use controls. Secondly, the effects of hurricanes on the critical natural processes working on the barrier islands in relation to human actions (such as dune stabilization and building) and the actions necessary to maintain the natural island equilibrium has not been addressed.

The action plan offered in this study takes consideration of these needed changes by adding more preventative measures in the form of building design criteria and various land use controls. The warning, relief, and rehabilitative activities of the Office of Civil Preparedness are maintained. Dune stabilization activities are ended. New conservation zoning regulations, new subdivision regulations, and building design criteria are added. Finally, a means of coordinating this program with the Coastal Area Management Act is included.

Footnotes

[1]Gilbert F. White, *Assessment of Research in Natural Hazards*, MIT Press, 1975, p. 245.

[2]Charles B. Carney and Albert V. Hardy, "North Carolina Hurricanes: A Listing and Description Which Have Affected the State," revised, 1967, from introduction.

[3]North Carolina Council of Civil Defense, *North Carolina Hurricane Project*, December, 1955, p. 25

[4]*Ibid.*

[5]*Ibid.*, p. 22

[6]Robert Dolan, Paul J. Godfrey, and William E. Odum, "Man's Impact on the Barrier Islands of North Carolina," *American Scientist*, March-April, 1973, p. 159

[7]*Ibid.*, p. 161.

[8]*North Carolina State Building Code*, Volume 1: General Construction, Revised 1967, Section 1205.

[9]*Ibid.*, Section 1408.2.

[10]Wallace, McHarg, Roberts, and Todd, *Comprehensive Land Use Plan City of Sanibel, Florida*, March, 1976, see sections on Mobile Homes and Flood Proofing.